§ 50. Heat Load Assessment to the ICRF Antenna Side Protector

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In the previous section the plasma heat load to the divertor plates was discussed. Here the heat load to the ICRF antenna side protector is introduced. In the previous section the local increase in Hα intensity was observed, and this phenomenon can be explained by the out-gassing from the graphite side protectors on the ICRF heating antennas. The temperature of them was not measured but it can be estimated from the previous experimental data. In the R&D period to test the transmission line for a high power of MW level and for the steady state operation in the ICRF heating system, the increase in the vacuum pressure often prevented from a long pulse operation in the high voltage test of the system including the antenna, the ceramic feed-though and the liquid impedance matching device. The graphite side protectors of the antenna were heated due to the RF induction heating and the temperature was increased with the operation time accompanying the vacuum pressure increase as shown in Fig.1. When the pressure reached to $1\text{x}10^{-3}$Pa, the RF breakdown occurred in the whole vacuum chamber (about 3m^3) and the interlock system monitoring the reflected power ceased the RF power output; then the graphite temperature was measured to be 300°C. The experimental data show the relation between the applied RF voltage V_{RF} and the achieved pulse length as shown in Fig.2 and the empirical scaling was obtained as follows;

$$T_C(°C) = 0.49V_{RF}^2(kV)(1-\exp(-\frac{t}{175}))+20$$

As the installed antenna is the same excect for the twisted configuration of the antenna surface, the temperature can be estimated to be 150°C in the long pulse discharge of 150sec using the above equation, which is plotted in Fig.2.

The heat load from the peripheral plasma must be assessed in addition to the RF inductive heat load; it is estimated using the plasma parameters measured by the scanning of Langmuir probe [1]. As the antennas are located at 7cm apart from the last closed magnetic surface, the heat load from the plasma is negligible.

Here it should be noted that the RF induced electric field in accordance with the Faraday's low forms the RF sheath potential in the thin plasma between the antenna strap and the side protector.

$$V_{SRF}(V) = 2.0\times10^{-8} f(MHz) I_{SRF}^{1/2} = 0.76(\frac{2P_{ICH}(W)}{R_P(Ohm)})^{1/2}$$

The numerical factor is attributed to the antenna dimension. The RF induced magnetic field was measured in the low power of 1W level between the antenna strap and the graphite protector, so the possibility of the RF sheath potential was assured experimentally. In the present experiment the applied frequency is f=38.47MHz. The RF sheath potential V_{SRF} is calculated to be 340V, when the measured P_{ICH}=250kW and R=2.5Ω are employed. When the existence of the plasma with an electron density n_e and an electron temperature T_e between the antenna strap and the graphite protector is assumed, the heat load is calculated as follows;

$$P_{SRF}(W/m^2) = 8.4\times10^3 n_e(10^{19}m^{-3}) T_e^{1/2}(eV)(\frac{2P_{ICH}(W)}{R_P(Ohm)})^{1/2}$$

Therefore the estimated temperature of the graphite protector is expressed as follows;

$$T_C(°C) = (\frac{2P_{ICH}}{R_P})^{1/2}\left\{1.23\times10^{-3}(\frac{2P_{ICH}}{R_P})^{1/2} + 12.8\cdot0.84\cdot n_e(10^{19}m^{-3})T_e^{1/2}(eV)\right\}$$
$$\times(1-\exp(-\frac{t}{175}))+20$$

where, 12.8 is the conversion coefficient from heat load to temperature increase deduced by using ANSYS code [2]. When there exists the plasma of $n_e=1\text{x}10^{17}\text{m}^{-3}$ and T_e=10eV, the graphite temperature will be T_C=250°C in the present long pulse discharge. We are preparing to install the far-infrared camera to measure the graphite protector and the divertor plates in the next experiment campaign.

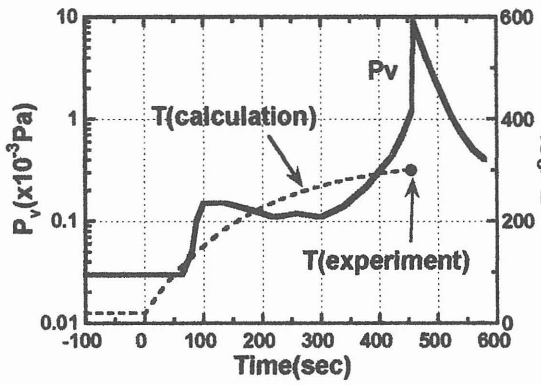

Fig.1 Time evolutions of the vacuum pressure and the temperature in the antenna side protector in the case of V_{RF}=25kV.

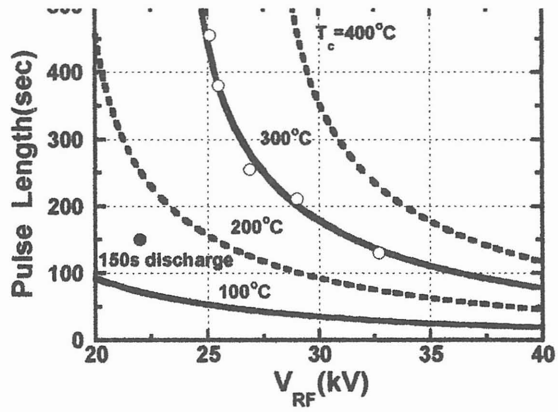

Fig.2 Temperature increase in the antenna side protector in the plane of the applied RF voltage V_{RF} and the pulse length.

References
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